

HOW IT WORKS

PC cooling

The faster a computer, the more heat it produces – so if you want to keep everything in good working order, you'll have to keep your cool. Tom Royal explains the different techniques used to take the heat out of your PC

Computers keep getting faster and more complicated, but the speed at which they run continues to be limited by one simple factor: heat. If you pass electrical current down a length of wire, it will heat up slightly. This is because the wire is a resistor, and some of the electrical energy that passes through it is converted into heat. This has many useful applications, such as in the construction of electric heaters, but when building a computer it becomes problematic. Computer processors also act as resistors, so the electricity passing through them causes them to heat up.

If you don't remove this heat from the processor, the best that can happen is that your computer senses danger and shuts itself down. If your PC doesn't shut down, the processor can become damaged or, ultimately, melt. This month, we'll explain the various ways that you can keep your computer chips cool, and how each one works.

PIPE DREAMS

Some processors can be cooled without fans or any other moving parts. The VIA C3 processor used on the tiny EPIA 5000 Mini-ITX motherboard, for example, generates so little heat that it can be cooled using a single heatsink. Heatsinks are made from metal that's shaped into fins. These fins have a far larger surface area than the flat surface of a processor, allowing

heat to be transferred to the air surrounding the processor more effectively. It's rare these days to see a computer processor that can be cooled using a small heatsink alone, but this kind of cooling is still commonplace on other motherboard chips that produce less heat.

More powerful processors can be cooled silently using large specialist heatsinks made by companies such as Zalman. These are made from dozens of flat sheets of copper or aluminium, giving them a vast surface area that can quickly dissipate a lot of heat. Even with this huge surface, though, most large heatsinks also use heat pipe technology. Heat pipes, which look like long, thin copper straws, ferry heat from the processor to the far ends of the cooler.

Heat pipes are fairly simple devices. They are made from a sealed metal tube filled with a liquid that vapourises above a certain temperature. This is often ethanol, but heat pipes can even be made using water. In the simplest heat pipes, no other materials are needed. One end of the pipe is placed near to the processor, and is heated up. Eventually, the liquid inside is changed into a vapour, which rises up the tube. The top end of the tube is further from the processor, and so cooler, so the vapour condenses back into a liquid. In doing so, it transfers heat to the walls of the pipe. In a large heatsink, this is carried away by adjacent metal fins. The contents of the pipe, now liquid again,

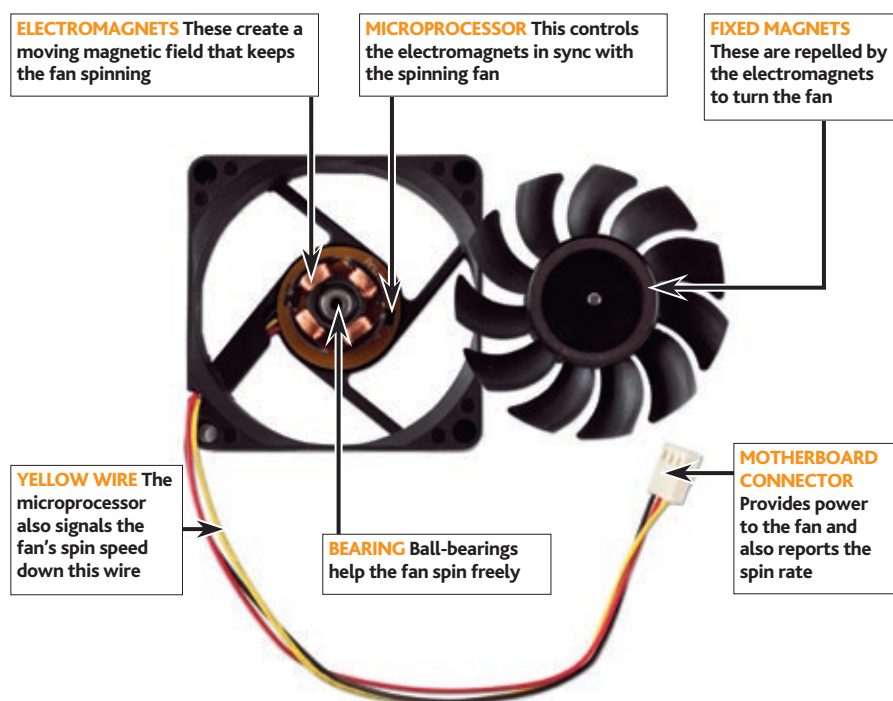
are carried by gravity back to the hot end, ready to boil again and carry away more heat.

This simple heat pipe design works only if the pipe is mounted vertically, with the heat source at its lower end. As most computers are built with the processor mounted vertically and the heatsink stretching out horizontally, it's not a feasible design. Fortunately, a slightly more complicated design allows heat pipes to function whichever way they are mounted. In these heat pipes, the inside of the metal tube is coated in a porous material called the wick. Just as the pores in a sponge or kitchen towel exert a force that sucks up water, this wick is filled with tiny grooves that suck up the liquid inside the pipe. This is known as capillary action. When the vapour condenses at the cool end of the tube, capillary action pulls the liquid back to the hot end, where any liquid in the wick has evaporated leaving empty pores.

The combination of large heatsinks and heat pipes allows for some ingenious cooling designs. The PCs made by Hush Technologies, for example, come in a case with large fins down each side that allow it to function as an enormous heatsink. Heat pipes connect the sides of the case to the processor, graphics chip and other components that get warm, ferrying heat to the case where it is dissipated into the surrounding air.

Zalman's TNN 500A case, a huge black metal box covered in fins, works in a similar way. You can fit your own motherboard, processor and graphics card, then connect the hot components to the case using heat pipes. It's one way to build a completely silent PC – that is, as long as you don't mind having a huge black case that looks like a prop from *2001: A Space Odyssey*.

A SYSTEM FAN DISSECTED

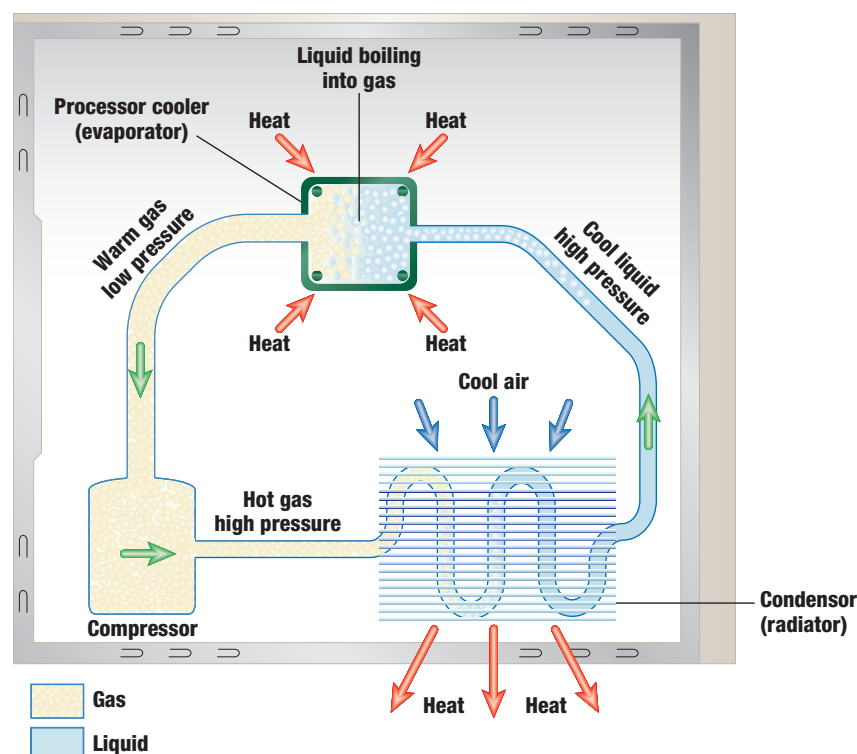


FANS FOR EVERYTHING

Although these specialist PC cases allow computers to operate with cooling provided only by heatsinks and heat pipes, most PCs rely on fans. Almost any desktop or notebook computer will have at least one fan mounted on the processor's heatsink. The principle by which heatsink-mounted fans help to keep the component underneath cool is simple. The fan constantly pushes cool air on to the heatsink, and at the same time moves hot air off the heatsink and away. This increases the amount of heat that's dissipated far beyond that possible using a heatsink alone.

Although some PCs use only a single heatsink-mounted fan, more powerful computers often have others mounted on the motherboard's Northbridge chip or graphics card. If these components get really hot, though, the fans can begin to re-circulate warm air around

Under pressure Phase-change cooling in action



the inside of the computer's case. This is why many desktop computers use additional fans, mounted at the front or the back of the case, to inject cool air from outside the computer and remove hot air.

Most fans used inside a computer are made using a very simple design. Most use a brushless DC electric motor. This uses a number of electromagnets, which are stationary and mounted in the fan casing, plus a regular magnet that is mounted in the moving part of the fan. The magnetic fields of the electromagnets need to be synchronised with the turning of the fan to keep pushing it in the right direction.

In a standard electric motor, this is done using brushes that form a circuit with the moving part of a fan to control the flow of current to two or more coils of wire. Brushless motors use an electronic control circuit instead to detect the position of the fan and regulate the electromagnets. Most good computer fans use ball bearings around the fan axle, allowing them to spin smoothly with little friction.

WATER WORKS

Most PCs can be cooled using a couple of heatsinks and one or two fans. The only significant downside of this method is noise: even one computer fan can be annoying in a quiet room. If you build a very powerful computer, with an overclocked processor and several graphics cards, it can begin to sound like a vacuum cleaner that recently inhaled a family of angry hornets. For this reason, some computer owners have turned to alternative methods of cooling. The most common is water cooling.

Water has a higher specific heat capacity than air. The specific heat capacity of a material

measures the amount of energy required to raise the temperature of a substance. Water has a specific heat capacity of over four joules per gram, compared to around one joule for air at room temperature. This means water has the potential to absorb four times as much heat as air.

Water-cooled computers sound exotic and complicated, but in fact the technology used is simple. Distilled water is carried in a plastic tube to an enclosed metal heatsink mounted on top of the component to be cooled. These heatsinks are called water blocks, and come in different varieties. Some deliberately create turbulence in the water as it passes over the metal surface, increasing the amount of heat that is transferred. Once it has passed over the water block the water is ferried away in another pipe. This might take it to another water block on a second component that needs to be cooled, or on to a radiator. Like the radiator in a car, this transfers heat from the water to the surrounding air.

Some water-cooled PCs use a radiator mounted at the back of the case, with a single large fan providing a flow of air over its surface. Other systems, such as Zalman's Reserator, use a larger external radiator that doesn't require a fan. Finally the water passes through a pump, which keeps it circulating, and a small reservoir of spare liquid, which ensures that the system is constantly full, before beginning a new cycle.

IT'S JUST A PHASE

Water cooling allows you to build a computer that's completely silent or, with the addition of some fans to cool the radiator, one that can suck heat away from an overclocked processor. If you want to build a computer that goes even faster,

though, and you don't mind a system that makes a racket, you might consider a phase-change cooling system.

Phase-change cooling sounds even more outlandish than water cooling, and it's certainly trickier to implement. Fitting a phase-change system involves building a cross between a computer and a domestic fridge, and relies on copper tubing, cooling fans, insulation and high-pressure gas. Although you could build one yourself, most people buy a ready-made system from companies such as Prometeia and Asetek. These come ready to connect to your existing computer, although you will still need to take a drill and possibly a hacksaw to your PC case.

The principle behind a phase-change cooling system is exactly the same as that of a fridge. Copper tubes create a closed circuit, allowing gas to flow in a loop around three main components: the compressor, the condenser and the evaporator.

The system works by exploiting the relationship between the temperature, pressure and phase (that is, liquid or gas) of a gas. The compressor sucks in gas from the end of its previous cycle, and increases its pressure significantly. This makes the gas become very hot. It then passes to the condenser, which is essentially a radiator. This allows the heat to dissipate into the surrounding air, usually with the aid of at least one fan. As the gas cools, the high pressure causes it to change phase into a liquid. This liquid passes through a thin pipe, up to the evaporator.

In a PC cooling system, the evaporator is placed next to the processor. At this point, the high-pressure liquid passes through a small opening into the low-pressure part of the system. The pressure of this side is kept low by the compressor, whose intake sucks gas from it. As the liquid passes into this low-pressure area it turns back into a gas; it boils. This process absorbs a large amount of heat from the processor. At low pressure, the gas is ready to be pulled into the compressor to repeat the process.

Phase-change cooling is very powerful, and allows you to overclock your processor to ludicrous speeds. It is expensive and loud, though, and most kits allow you to cool only the processor, so you'll still need fans or water cooling for your graphics card.

OIL IN A DAY'S WORK

If strapping the working parts of a refrigerator to your computer sounds a little too pedestrian, you could consider oil cooling. Several people have successfully built computers in which the processor and motherboard are completely submerged in a liquid that conducts heat but not electricity, such as cooking oil. If you can get your processor running fast enough, you might even be able to cook potato chips while you keep your computer chips cool. ☞

FURTHER INFORMATION

Water-cooling kit with enormous external radiator

www.quietpc.com/gb-en-gbp/products/watercooling/reserator1-v2

Asetek phase-change cooling kits
www2.asetek.com

Oil-cooled PC

http://tomshardware.co.uk/2006/01/09/strip_out_the_fans1